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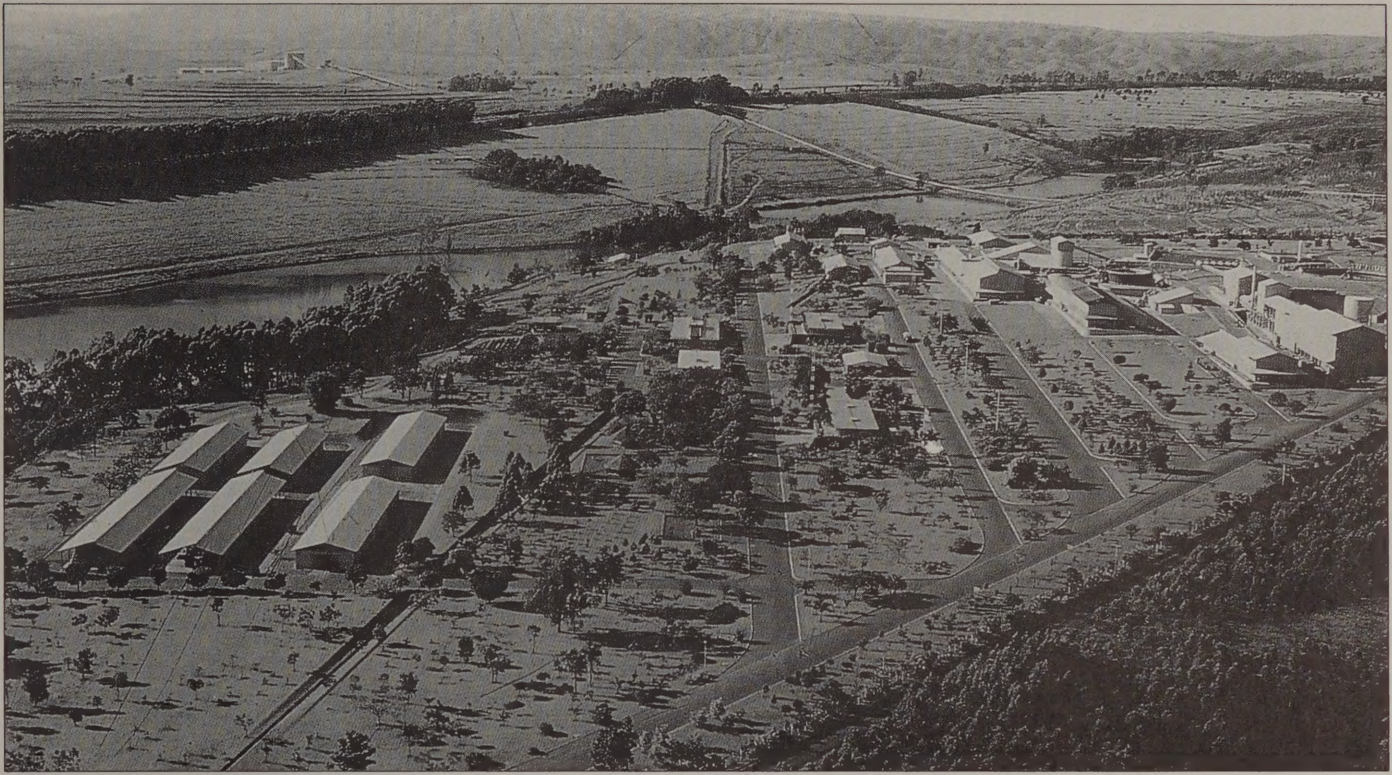

COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

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ANNUAL REPORT

COLUMBIUM (NIOBIUM) AND TANTALUM

MARCH 3, 1849

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

November 1991

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COVER PHOTO:
View of Cia. Brasileira de Metalurgia e Mineração's (CBMM) columbium mine facility in Araxa, Brazil. CBMM is the world's largest columbium producer and leading exporter of upgraded columbium products. (Photo is courtesy of CBMM and Niobium Products Co. Inc).

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COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

Mr. Cunningham, a physical scientist with 11 years of U.S. Bureau of Mines experience, has served as the commodity specialist for columbium and tantalum since 1983. Domestic survey and trade data were prepared by Cheryl M. Mack, mineral data assistant; and columbium and tantalum world production data, by country, were prepared by Audrey D. Wilkes, international data coordinator.

Columbium is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. Columbium is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Acceptable substitutes are available for some columbium applications, but in most cases they are less desirable. Tantalum is used mostly in the electronics industry, mainly in capacitors, and in aerospace and transportation applications. Tantalum is also critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications. Domestic columbium and tantalum resources are of low grade and are not commercially recoverable. The last significant mining of columbium and tantalum was during the Korean conflict when increased military demand resulted in columbium and tantalum ore shortages.

The United States continued to be dependent on imports of columbium and tantalum materials, with Brazil remaining the major source for columbium imports and the Federal Republic of Germany the major source for tantalum imports. Columbium price quotations were unchanged for the year, and tantalum prices remained stable.

The National Defense Stockpile (NDS) requirement (goal) for the columbium group nearly tripled in accordance with the National Defense Authorization Act for Fiscal Years 1990 and 1991. Also, to ensure future availability to the United States, the Defense Logistics Agency (DLA) awarded contracts for purchase of tantalum minerals for the NDS.

Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium rose slightly, with demand for columbium in superalloys at the highest level since 1986. Tantalum consumption was up for the year, aided by increased demand from the electronics industry.

DOMESTIC DATA COVERAGE

Domestic production data for ferrocolumbium are developed by the U.S. Bureau of Mines from the annual voluntary domestic survey for ferroalloys. Of the four operations to which a survey request was sent, three responded. Thus, ferrocolumbium production data for 1990 were incomplete at the time this report was prepared.

BACKGROUND—COLUMBIUM

Columbium and niobium are synonymous names for the chemical element with atomic number 41; columbium was the first name given, and niobium was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity relatively well, has a high melting point (2,480° C), is readily fabricated, and is highly resistant to many chemical environments. Columbium exhibits superconductivity at about 9° K, a temperature still too low for most commercial applications. (Superconductivity is the virtual loss of electrical resistance that occurs at a specific material dependent temperature and results in energy conservation and more rapid operation of electrical circuits.)

Definitions, Grades, and Specifications

Columbium pentoxide (oxide) is a stable, white- to buff-colored compound that is produced in metallurgical, ceramic, and optical grades. Purity of oxide generally exceeds 99%.

Ferrocolumbium is categorized into three grades by American Society for Testing and Materials (ASTM) Specification A550: low-alloy steel grade, alloy and stainless steel grade, and high-purity grade. For all grades, the composition is approximately 65% columbium, with the balance iron; principal impurities are aluminum, silicon, and tantalum. Nickel columbium typically contains 63% columbium, with the balance being nickel. Aluminum, iron, silicon, and tantalum are the principal impurities.

Columbium carbide is available as a powder containing about 87% columbium and the balance as carbon.

Columbium metal is available in many forms and shapes. Purity of unalloyed metal is usually more than 99%, with attention mainly given to iron, tantalum, and zirconium as metallic impurities and carbon, hydrogen, nitrogen, and oxygen as interstitial impurities. Alloys with hafnium, tantalum, titanium, tungsten, and zirconium are of most commercial importance. Chemical and physical standards for columbium and columbium alloy mill shapes are given in ASTM

Specifications B391-B394, B652, and B654-B655.

Products for Trade and Industry

Columbium, in the form of ferrocolumbium, is used worldwide, principally as an additive to improve the strength and corrosion resistance of steel. Columbium-containing high-strength and corrosion resistant steel is used in applications such as high-strength linepipe, structural members, lightweight components in cars and trucks, and exhaust manifolds. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in nickel-, cobalt-, and iron-base superalloys for applications such as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Columbium-base alloys are also used in aerospace applications such as rocket nozzles. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten carbide-base material. It is usually used with carbides of metals such as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of high-purity ferrocolumbium, nickel columbium, columbium metal, and columbium carbide.

Geology-Resources

Columbium is almost always found in nature as an oxide in association with other minerals, but not in elemental form nor as a sulfide. Columbium has an overall crustal abundance estimated as 20 parts per million and a strong geochemical coherence with tantalum. Pyrochlore and bariopyrochlore (also known as pandaite), its barium analog, have become the main sources of columbium. The minerals contain little tantalum, having a columbium oxide-to-tantalum oxide ratio of 200:1 or greater. Pyrochlore and bariopyrochlore are commonly found in the interior parts of alkalic rock complexes, frequently in association with minerals of such other elements as thorium, titanium, uranium, and those of the rare earths. Columbite, the columbium-rich member of the columbite-tantalite isomorphous series, is normally found in intrusive pegmatites and in biotite and alkalic granites. However, because most such deposits relatively high in columbium content are small and erratically distributed, most columbite has been obtained as a byproduct of mining for other commodities, mainly tin.

Reserve and reserve base data for columbium are shown in table 1 and are based on a judgmental appraisal of current information. Reserve base is defined as the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. The reserve base may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. Reserves are defined as that part of the reserve base that could be economically extracted or produced at the time of determination.

Technology

Exploration.—Columbium deposits of economic interest are most likely to be found in alkalic rock complexes and associated carbonatites. Aerial photography and geological mapping can be used to reveal alkalic complexes, which frequently occur with circular geometry and concentric rock arrangement. Test pitting and panning can be used to explore placer deposits for columbium by virtue of the high specific gravity of columbium minerals. The columbium content of samples can be determined rapidly by means of truck-mounted spectrographic equipment and X-ray fluorescence spectroscopy.

Mining.—Pyrochlore has been mined mainly by mechanized open pit, under ground stoping methods, or a combination of both. Currently, all mining for pyrochlore in Brazil is open pit, whereas in Canada, underground mining is being done via a large-diameter blasthole method. Ore, with host rock, is usually dislodged from a working face with explosives. Beneficiation of the ore, after it has been finely ground, is achieved primarily by various flotation procedures combined with magnetic separation to remove iron minerals. A chloridizing and leaching process can also be employed to lower barium, lead, phosphorus, and sulfur contents. Methods used to mine columbite have ranged from simple hand operations in small pegmatite mines to hydraulic monitors and dredges at placer deposits.

Beneficiation.—Pyrochlore concentrates are used solely in the manufacture of ferrocolumbium for steelmaking. Aluminothermy, the process being used for making steelmaking-grade ferrocolumbium from pyrochlore concentrates, is carried out in batches. As practiced by Cia. Brasileira de Metalurgia e Mineração (CBMM) in Brazil, a mixed charge of concentrate, iron oxide (as hematite), fine aluminum powder, and slagging agents is reacted to produce ferrocolumbium in a refractory-lined, cylindrical steel shell open at the top and resting upon a lined silica sand bed. Also, processes have been developed for production of columbium oxide through treatment of ferrocolumbium produced from pyrochlore concentrates. This technology is being used to produce commercial quantities of columbium oxide suitable for the manufacture of high-purity ferrocolumbium, nickel columbium, and columbium metal.

TABLE 1

WORLD COLUMBIUM RESERVES AND RESERVE BASE, 1990

(Thousand pounds columbium content)

Country	Reserves	Reserve base[1]
Brazil	7,300,000	8,000,000
Canada	300,000	900,000
Nigeria	140,000	200,000
United States	—	(2)
Zaire	70,000	200,000
Other market economy countries	14,000	19,000
World total (rounded)	7,800,000	9,300,000

[1] The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

[2] Negligible.

In the extraction of columbium from other mineral concentrates and tin slags, modern technology makes use mainly of digestion with hydrofluoric acid followed by liquid-liquid extraction with methyl isobutyl ketone (MIBK). This procedure efficiently recovers both columbium and tantalum in the form of separate streams that then can be further processed individually into oxides and metal. Columbium oxide is precipitated from the columbium stream by ammonia and then purified and calcined.

Columbium oxide is aluminothermically reduced batchwise to produce high-purity ferrocolumbium, nickel columbium, and columbium metal. Aluminothermically produced columbium metal is commonly purified to remove aluminum and other contaminants by remelting it in an electron-beam furnace. Several remelts may be required before the desired level of purity is reached and a ductile ingot has been produced. The basic method for production of columbium carbide is reduction of columbium oxide by carbon at high temperature under vacuum or a protective atmosphere.

Recycling.—Columbium used in steelmaking and in superalloy manufacture is essentially a dissipative use, and little is reclaimed. However, when strict scrap segregation practices are followed, small quantities of columbium-bearing superalloy scrap are recycled. Aside from sales to alloy melters, columbium metal scrap has not been recycled to any extent other than in-house as home scrap by processors.

Byproducts and Coproducts

In Africa, Australia, Brazil, Malaysia, and Thailand, columbium, as well as tantalum, is produced as a byproduct and/or coproduct of tin mining. Columbium and tantalum can also be recovered economically from some tin slags, which constitute an important raw material source for high-purity columbium and tantalum. Other elements frequently associated with columbium deposits include rare earths, thorium, titanium, and uranium; some of these have been recovered along with columbium in the past and may be coextracted in the future.

Substitutes

For established applications of both columbium-bearing steels and superalloys, substitution of some alternative steel or alloy requiring less columbium ordinarily lowers performance and/or cost effectiveness. In some high-strength low-alloy (HSLA) steels, use of columbium as a microalloying element competes with use of such elements as molybdenum, titanium, and vanadium. In other HSLA steels, it may be desirable to use one or more of these elements along with columbium in complementary fashion. Tantalum is a costly potential substitute for columbium in superalloys. Titanium can be used instead of columbium in stainless steel to improve corrosion resistance.

Economic Factors

Prices.—The price of columbium contained in concentrates, in terms of actual prices and in constant 1982 dollars, has been relatively stable for the period shown in table 2. Actual prices reported are based on historical price quotations or best available information from producers. Additionally, prices for products based on columbium concentrates have been stable over the past decade. At yearend 1990, the published price for columbium oxide was $7.64 per pound of oxide, the published price for regular-grade ferrocolumbium was $6.58 per pound of contained columbium, the published price for high-purity ferrocolumbium was $17.50 per pound of contained columbium, the published price for nickel columbium was $19.50 per pound of contained columbium, and the published price for columbium metal was at a range of $30 to $50.

Depletion Provisions.—U.S. columbium-producing companies are granted a depletion allowance of 22% for domestic production of columbium minerals and 14% on foreign production.

BACKGROUND—TANTALUM

Tantalum is a refractory metal that is ductile, easily fabricated, has a high melting point (2,996° C), is highly resistant to corrosion by acids, and is a good conductor of heat and electricity. It combines readily with other refractory metals such as hafnium and tungsten to form alloys having high-temperature strength and stability. Tantalum forms highly stable anodic films and exhibits a rectifying, or electronic valve, action in an electrolyte. Tantalum is twice as dense as steel with a specific gravity of 16.6.

TABLE 2

TIME-PRICE RELATIONSHIPS FOR COLUMBIUM

Year	Average annual price, dollars per pound of contained columbium in concentrates	
	Actual price	Based on constant 1982 dollars
1954	4.86	18.48
1955	1.93	7.10
1956	1.79	6.37
1957	1.68	5.77
1958	1.54	5.19
1959	1.54	5.07
1960	1.73	5.60
1961	1.43	4.58
1962	1.36	4.26
1963	1.36	4.20
1964	1.36	4.13
1965	1.34	3.96
1966	1.43	4.09
1967	1.42	3.96
1968	1.42	3.77
1969	1.42	3.57
1970	1.65	3.93
1971	1.65	3.72
1972	1.87	4.02
1973	1.97	3.98
1974	2.23	4.13
1975	2.23	3.76
1976	2.73	4.33
1977	5.53	8.22
1978	3.69	5.11
1979	3.79	4.82
1980	4.55	5.31
1981	4.87	5.18
1982	4.83	4.83
1983	4.73	4.55
1984	4.71	4.37
1985	4.63	4.17
1986	3.78	3.32
1987	3.71	3.16
1988	3.71	3.06
1989[e]	[r]3.93	[r]3.11
1990[e]	3.93	2.99

[e]Estimated. [r]Revised.

Definitions, Grades, and Specifications

Metallic forms of tantalum are produced chiefly in unalloyed form or alloyed with up to about 10% tungsten.

Unalloyed metal and alloys with tungsten are available as ingot, plate, sheet, strip, bar, rod, wire, and tubing in accordance with ASTM Specifications B364, B365, and B521. Allowable impurity levels do not exceed 0.3% in most cases; the main impurities are columbium and oxygen, plus tungsten in the case of unalloyed tantalum. Purity of tantalum metal powder is usually about 99.9%. Depending on powder usage, impurities that must be controlled consist mainly of calcium, carbon, columbium, iron, nickel, nitrogen, oxygen, silicon, and sodium. Commercial tantalum carbide usually contains about 93% tantalum and about 6.3% carbon.

Products for Trade and Industry

The major end use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. Applications for tantalum capacitors include computers, communication systems, and instruments and controls for aircraft, missiles, ships, and weapon systems. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelflife. Because of its high melting point, good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are employed in aerospace structures and jet engine components. Tantalum carbide, used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in cemented-carbide cutting tools, wear-resistant parts, farm tools, and turning and boring tools. Because of its excellent corrosion resistant properties, tantalum mill and fabricated products are used in the chemical industry in applications such as heat exchangers, evaporators, condensers, pumps, and liners for reactors and tanks.

Geology-Resources

The principal source of tantalum is an isomorphous series of minerals containing columbium, iron, manganese, and tantalum oxides. Tantalum and columbium have strong geochemical affinity and are found together in most rocks and minerals in which they occur. Tantalite-columbite occurs mainly as accessory minerals disseminated in granitic rocks or in pegmatites associated with granites. The microlite-pyrochlore mineral series is also a source of tantalum. These minerals consist essentially of complex oxides of calcium, columbium, sodium, and tantalum in combination with hydroxyl ions and fluorides. Microlite occurs mainly in the albitized zones of granite pegmatites, often associated with tantalite or columbite. Struverite is a low-grade source of tantalum recoverable from tin mining wastes in Southeast Asia. Struverite is a variation of the titanium mineral rutile. Tantalum is also obtained through byproduct recovery from tantalum-bearing tin slags, principally from smelters in Brazil and Southeast Asia.

Reserve and reserve base data for tantalum are shown in table 3 and are based on a judgmental appraisal of current information. Reserve base is defined as the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. The reserve base may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. Reserves are defined as that part of the reserve base that could be economically extracted or produced at the time of determination.

Technology

Exploration.—Exploration for tantalum is generally pursued on the basis of its known frequent association with tin and certain other elements in pegmatite environments, some features of which can be distinguished by aerial photography. Application of X-ray fluorescence analysis techniques has been helpful in measuring tantalum at the low concentrations at which it occurs. The high specific gravity of tantalum minerals makes it possible to reveal their presence in placer deposits by test pitting and panning.

Mining.—Most tantalum-related mining developments in the past generally were small, relatively high-cost intermittent operations that depended on the recovery of byproduct or coproduct minerals for economic viability. Future mine development will shift more to primary tantalum sources, notably operations in Australia.

Both alluvial and residual tantalum and tantalum-containing tin deposits are normally mined by hand, by hydraulic monitors, by dredges, or by mechanized open pit mining. The mining of pegmatite deposits, which may be either open pit or underground, is carried out by blasting, transporting, and crushing the rock to free the tantalum and associated coproduct minerals. The materials are then concentrated by wet gravity methods (sluices, jigs, spirals, and tables) and finally separated from associated minerals by gravity and electrostatic and electromagnetic processes.

TABLE 3

WORLD TANTALUM RESERVES AND RESERVE BASE, 1990

(Thousand pounds tantalum content)

Country	Reserves	Reserve base[1]
Australia	10,000	20,000
Brazil	2,000	3,000
Canada	4,000	5,000
Malaysia	2,000	4,000
Nigeria	7,000	10,000
Thailand	16,000	20,000
United States	—	(2)
Zaire	4,000	10,000
Other market economy countries	3,000	4,000
World total	48,000	76,000

[1] The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

[2] Negligible.

Tantalum is recovered from slags produced at tin smelters throughout the world. Tantalum content varies in tin slag depending on ore and smelting practice.

Beneficiation.—Tantalum mineral concentrates and tin slags are the predominant feed materials for preparation of tantalum metal and compounds. Both raw materials usually contain recoverable amounts of columbium as well. Depending on circumstances, tin slags may be used directly for extraction of tantalum or they may be first upgraded. Upgrading is typically performed by means of an electric furnace process that yields a synthetic concentrate.

In the extraction of tantalum from these source materials, technology makes use mainly of digestion with hydrofluoric acid followed by liquid-liquid extraction with MIBK. This procedure efficiently recovers both tantalum and columbium in the form of separate streams that then can be further processed individually into salts, oxides, and metal. The two streams are produced by a series of countercurrent extractions that also remove impurities. The tantalum product stream is a fluotantalic acid solution from which either potassium fluotantalate (K-salt), by addition of potassium chloride or fluoride, or tantalum pentoxide, by addition of ammonia, can be precipitated. Reducing K-salt by sodium is the standard commercial method for making tantalum metal. The product of sodium reduction is a powder that is consolidated by a pressing, vacuum sintering, and melting sequence.

Tantalum carbide can be manufactured by several methods, the most common being solid-state reaction between tantalum oxide and carbon. Tantalum carbide can also be made by reacting metallic tantalum directly with carbon.

Recycling.—Recycling of tantalum largely takes place within the processing and product-producing industry and is mostly runaround or home scrap that is consumed internally. In addition, quantities of tantalum are recycled indirectly in the form of used tantalum-bearing cutting tools and high-temperature alloy melting scrap.

Byproducts and Coproducts

Economic exploitation of tantalum minerals often is dependent on the price of associated recoverable byproduct or coproduct minerals, principally tin and columbium. Tantalite-columbite minerals occur in deposits associated with beryllium, lithium, rare-earth, tin, titanium, tungsten, uranium, and zirconium minerals. Minerals associated with tantalum in pegmatite deposits include beryl, feldspar, lepidolite, mica, pollucite, and spodumene. Tantalum and columbium can also be recovered economically from some tin slags, which constitute an important raw material source for tantalum and high-purity columbium. Tantalum is usually extracted in conjunction with columbium in much the same type of equipment.

Substitutes

Substitution for tantalum is usually made at a performance or economic penalty for most uses. Also, substitution requires both investment and experimentation and does not necessarily occur quickly. Aluminum and ceramics compete strongly with tantalum for use in electronic capacitors. In cemented carbides, columbium carbide and columbium-hafnium carbide can take the place of tantalum carbide in some cutting tools. Replacements for tantalum in corrosion-resistant equipment are columbium, glass, platinum, titanium, and zirconium. Columbium, hafnium, molybdenum, tungsten, and some platinum-group metals can be substituted for tantalum in high-temperature applications.

Economic Factors

Prices.—Time-price relationships for tantalum contained in concentrates in terms of actual prices and in constant 1982 dollars are shown in table 4. Actual prices reported are based on historical price quotations or best available information from producers. The prices show large swings between the high and low in response to market conditions, with recent year pronounced maximums occurring in 1980 and 1988. A 7-year trend of declining price, 1967–73, was followed by a trend of rapid price increase that was sustained through midyear 1980. The record price levels during this period were attributed in part to a state of panic buying influenced by anticipated greater tantalum demand, amidst concerns at the time of a shrinking world tantalum supply. The high prices brought about substitution for tantalum and more widespread search for and development of new tantalum sources. However, prices began declining by yearend 1980 and, by midyear 1986, were the lowest since first quarter 1977, hastened by a weak

TABLE 4

TIME-PRICE RELATIONSHIPS FOR TANTALUM

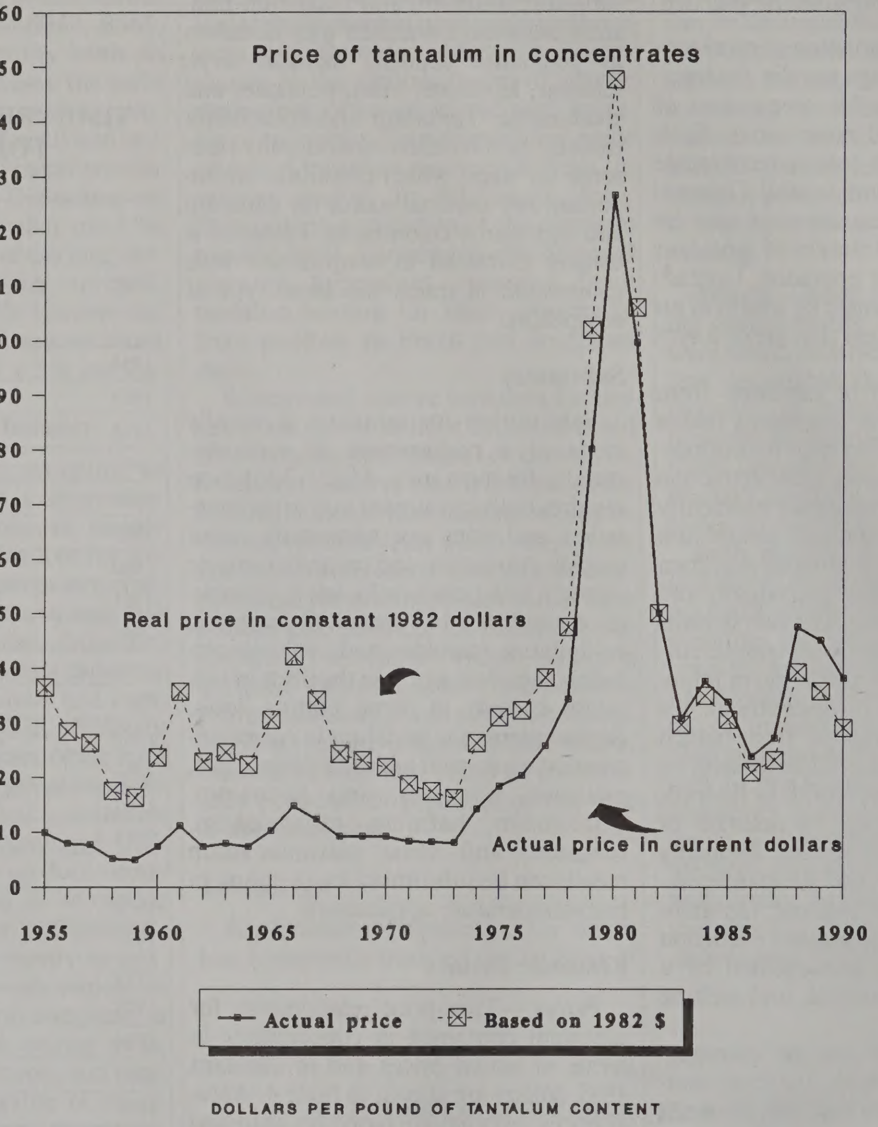
Year	Average annual price, dollars per pound of contained tantalum in concentrates[1]	
	Actual price	Based on constant 1982 dollars
1954	9.77	37.15
1955	9.91	36.43
1956	7.96	28.33
1957	7.63	26.22
1958	5.18	17.44
1959	4.92	16.18
1960	7.28	23.56
1961	11.11	35.61
1962	7.29	22.85
1963	7.93	24.48
1964	7.31	22.22
1965	10.26	30.36
1966	14.72	42.06
1967	12.24	34.09
1968	9.13	24.22
1969	9.15	22.99
1970	9.15	21.79
1971	8.26	18.60
1972	8.09	17.40
1973	8.00	16.16
1974	14.13	[r]26.17
1975	18.32	30.89
1976	20.31	32.19
1977	25.64	38.10
1978	34.19	47.35
1979	80.00	101.78
1980	126.37	147.46
1981	99.51	105.86
1982	49.95	49.95
1983	30.60	29.45
1984	37.44	34.76
1985	33.68	30.37
1986	23.74	20.86
1987	27.08	23.07
1988	47.37	39.05
1989	44.93	35.57
1990	38.06	28.94

[r] Revised.

[1] 60% basis, combined tantalum and columbium pentoxides.

FIGURE 1

TIME-PRICE RELATIONSHIPS FOR TANTALUM



tantalum demand and an increase in tantalum material stockpiles. Subsequently, prices rebounded through yearend 1988 and were at the highest level since the third quarter of 1981, responding to increased demand for feed materials along with the drawdown of stockpiles.

Depletion Provisions.—U.S. tantalum-producing companies are granted a depletion allowance of 22% for domestic production of tantalum minerals and 14% on foreign production.

ANNUAL REVIEW—COLUMBIUM AND TANTALUM

Legislation and Government Programs

Under the offset concept for the NDS, less than 25% of the goal for columbium concentrates and 37% of the goal for tantalum minerals were met (table 7).

In June, the goal for the columbium group in the NDS was raised to 12,520,000 pounds of contained columbium from 4,850,000 pounds of contained columbium. The action to nearly triple the columbium stockpile goal was taken under the authority vested in the Assistant Secretary of Defense and in accordance with the National Defense Authorization Act for Fiscal Years 1990 and 1991. This followed the U.S. Department of Defense findings concerning military requirements for strategic and critical materials.

TABLE 5

SALIENT COLUMBIUM STATISTICS

(Thousand pounds of columbium content unless otherwise specified)

	1986	1987	1988	1989	1990
United States:					
Mine production of columbium-tantalum concentrates	—	—	—	(1)	(1)
Releases from Government excesses	—	—	—	—	—
Consumption of raw materials[e]	W	W	NA	NA	NA
Production of ferrocolumbium	W	W	NA	NA	NA
Consumption of primary products: Ferrocolumbium and nickel columbium[e]	4,995	5,179	5,876	[r]5,377	5,699
Exports: Columbium metal, compounds, alloys (gross weight)[e]	120	130	120	NA	NA
Imports for consumption:					
Mineral concentrates[e]	1,320	2,010	1,750	2,680	2,480
Columbium metal and columbium-bearing alloys[e]	5	42	32	26	5
Ferrocolumbium[e]	3,432	4,016	4,238	5,316	4,183
Tin slags[e] [2]	W	W	NA	NA	NA
World: Production of columbium-tantalum concentrates[e]	32,149	[r]20,633	[r]36,917	[r]30,286	27,054

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

TABLE 6

SALIENT TANTALUM STATISTICS

(Thousand pounds of tantalum content unless otherwise specified)

	1986	1987	1988	1989	1990
United States:					
Mine production of columbium-tantalum concentrates	—	—	—	(1)	(1)
Releases from Government excesses	—	—	—	—	—
Consumption of raw materials[e]	W	W	NA	NA	NA
Exports:					
Tantalum ores and concentrates (gross weight)[2]	71	103	214	8	2
Tantalum metal, compounds, alloys (gross weight)	392	413	487	[r]358	374
Tantalum and tantalum alloy powder (gross weight)	160	193	278	211	182
Imports for consumption:					
Mineral concentrates[e]	280	220	400	1,100	660
Tantalum metal and tantalum-bearing alloys[3]	46	60	128	82	47
Tin slags[e] [4]	W	W	NA	NA	NA
World: Production of columbium-tantalum concentrates[e]	473	605	[r]641	[r]835	758

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Includes reexports.

[3] Exclusive of waste and scrap.

[4] Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

Also in June, the DLA awarded contracts to purchase 200,000 pounds of tantalum pentoxide (Ta_2O_5) contained in tantalum natural minerals and concentrates for the NDS. The minerals and concentrates were to be grade 1 as defined in National Stockpile Purchase Specification P-113a, effective August 3, 1981, requiring a minimum Ta_2O_5 content of 25% and a minimum combined Ta_2O_5 plus columbium pentoxide (Cb_2O_5) content of 55%.

The awards were made to O'Dell Construction Co., Prattville, AL, a domestic producer, and Sogem-Afrimet, New York, NY, for two allotments of 100,000 pounds each for placement in the NDS storage depot at New Haven, IN, and Somerville, NJ, respectively. The tantalum materials are to be delivered to the NDS within 2 years of contract award. The material to be provided by O'Dell Construction reportedly will be produced at a mine in Rockford, AL.

Offers for the first allotment ranged from $37.00 to $45.00 per pound of contained tantalum pentoxide. O'Dell Construction Co. was the low bidder. Offers for the second allotment ranged from $36.62 to $47.00 per pound of contained tantalum pentoxide. Sogem-Afrimet was the low bidder.

At about the time the bids were opened, the Metals Week and Metal Bulletin published price for tantalite ore ranged from $27.00 to $28.50 and $27 to $33 per pound of tantalum pentoxide, respectively.

The U.S. Department of Defense's planned targets of opportunity for fiscal year 1991 included the purchase of an additional 200,000 pounds of tantalum pentoxide contained in tantalum natural minerals and concentrates for the NDS.

Strategic Considerations

The high degree of import reliance for columbium and tantalum continues to be the principal strategic problem faced by the United States. In the case of both columbium and tantalum, there has been no significant mining since the 1950's. Domestic columbium and tantalum resources are of low grade, some mineralogically complex, and most are not currently commercially recoverable. To ensure a supply of columbium and tantalum during an emergency, goals for both materials have been established for the NDS. However, inventories for both materials are substantially under set

TABLE 7

COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT INVENTORIES AS OF DECEMBER 31, 1990

(Thousand pounds of columbium or tantalum content)

Material	Stockpile goals	National Defense Stockpile inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Columbium:				
Concentrates	13,270	1,150	869	[1]2,019
Carbide powder	100	21	—	21
Ferrocolumbium	—	598	333	[1]931
Metal	—	45	—	[1]45
Total	(2)	1,814	1,202	3,016
Tantalum:				
Minerals	8,400	1,686	1,152	[3]2,838
Carbide powder	—	29	—	[3]29
Metal	—	201	(4)	[3]201
Total	(2)	1,916	1,152	3,068

[1] All surplus ferrocolumbium and columbium metal were used to offset columbium concentrates shortfall. Total offset was 1,148,000 pounds.

[2] Overall goals, on a recoverable basis, total 12,520,000 pounds for the columbium metal group and 7,160,000 pounds for the tantalum metal group.

[3] All surplus tantalum carbide powder and tantalum metal were used to offset the tantalum minerals shortfall. Total offset was 271,000 pounds.

[4] 100 pounds.

Source: Defense Logistics Agency, Defense National Stockpile Center.

goals. Consequently, a degree of vulnerability still remains.

Issues

At the start of the 1980's, there were four major processors of columbium- and tantalum-bearing source materials (feedstocks). One of the operations was shut down in 1985, and another shut down its processing operation at yearend 1989. Of the remaining two companies, one is dedicated solely to the processing of columbium materials, whereas the other company processes both columbium and tantalum materials. The NDS goals and inventory for both columbium and tantalum are mostly for source materials. Thus, it is assumed that the United States would have on hand in an emergency adequate processing capacity for conversion of the material to an upgraded form and quality required by the critical end uses. However, the United States has become more reliant on the processing capability of foreign sources and the availability of intermediate products from those sources.

Production

In 1990, there were only two processors of columbium- and tantalum-bearing source materials that were integrated from raw material processing to columbium and tantalum end products: Cabot Corp. for columbium and tantalum processing and Shieldalloy Metallurgical Corp., dedicated solely to columbium processing. NRC Inc. was a major producer of tantalum products, and Reading Alloys Inc. and Teledyne Wah Chang Albany were major producers of high-purity columbium products. Kennametal Inc. was the major producer of columbium and tantalum carbides.

Additionally, Thai Tantalum Co. Ltd. (TTA), formally Thailand Tantalum Industry Corp. Ltd. (TTIC) of Bangkok, reportedly began production of a range of precursor powders at its tantalum facility in Muskogee, OK, in late 1990. The powders produced at Muskogee were to be shipped to TTA's other tantalum facility in Gurnee, IL, where the powders will be upgraded to capacitor-grade quality. Commercial-scale production of the capacitor powders at Gurnee was to commence in early 1991.

Buttes Gas & Oil Co. reportedly entered into an agreement with Teck Corp., Vancouver, British Columbia, to develop Buttes' Powderhorn titanium property in Gunnison, CO. Teck would earn a 60% interest in Powderhorn by taking the property to commercial production. The property reportedly contains significant quantities of columbium in the form of the mineral perovskite.

Consumption and Uses

Overall reported consumption of columbium as ferrocolumbium and nickel columbium rose by 6% compared with that of 1989. Consumption of columbium by the steelmaking industry was up slightly in line with a small increase in raw steel production, with virtually no change in the percentage of columbium usage per ton of steel produced. Consumption in all reported steel end-use categories was down with the exception of carbon steels, which increased by 15%. Demand for columbium in superalloys was up by 27% to the highest level since 1986. That portion used in the form of nickel columbium increased to more than 470,000 pounds to the highest level since 1985. U.S. columbium consumption, by end use, is shown in figure 2.

Overall consumption of tantalum was up from that of 1989, aided by increased demand from the electronics sector in the form of tantalum capacitor-grade powder. Tantalum shipments data were no longer available from the Tantalum Producers Association (TPA). The TPA was dissolved in December 1990. Factory sales of tantalum capacitors rose by 10%, as reported by the Electronic Industries Association. Additionally, the trend in recent years toward miniaturization of tantalum capacitors in the electronics industry continued. U.S. tantalum consumption, by end use, is shown in figure 3.

Markets and Prices

A published price for pyrochlore concentrates was not available. The published price for pyrochlore produced in Canada was suspended in early 1989, and a price for Brazilian pyrochlore has not been available since 1981 when exports were stopped. Unchanged since midyear 1989, the Metals Week published price for regular-grade ferrocolumbium was $6.00 to $6.58 per pound of contained columbium, f.o.b. shipping port.

The Metals Week published price for high-purity ferrocolumbium containing 62% to 68% columbium remained at $17.50 per pound of contained columbium, f.o.b. shipping point, and the

TABLE 8

MAJOR DOMESTIC COLUMBIUM AND TANTALUM PROCESSING AND PRODUCING COMPANIES IN 1990

Company	Plant location	Products[1]						
		Metal[2]		Carbide		Oxide and/or salts		FeCb and/or NiCb
		Cb	Ta	Cb	Ta	Cb	Ta	
Cabot Corp.	Boyertown, PA	X	X	—	—	X	X	—
Do.	Revere, PA	—	—	—	—	—	—	X
Kennametal Inc.	Latrobe, PA	—	—	X	X	—	—	—
NRC Inc.[3]	Newton, MA	X	X	—	—	—	—	—
Reading Alloys Inc.	Robesonia, PA	—	—	—	—	—	—	X
Shieldalloy Metallurgical Corp.	Newfield, NJ	—	—	—	—	—	—	X
Teledyne Inc.: Teledyne Wah Chang Albany Div.	Albany, OR	X	—	—	—	X	—	X

X Indicates processor and/or producer.

[1] Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium.

[2] Includes miscellaneous alloys.

[3] Jointly owned by Bayer U.S.A. and Hermann C. Starck Berlin KG.

published spot price for columbite ore continued at a range of $3.00 to $3.50 per pound of contained Cb_2O_5 and Ta_2O_5, c.i.f. U.S. ports. Also unchanged for the year, the published price for nickel columbium was $19.50 per pound of contained columbium, the published price for columbium oxide was $7.64 per pound of oxide, and the published price for columbium metal was at a range of $30 to $50.

The Metals Week published spot price for tantalite ore, on the basis of 60% combined Cb_2O_5 and Ta_2O_5, c.i.f. U.S. ports, began the year at $26 to $28 per pound, rose to $34 to $36 by midyear, and then widened in the fourth quarter to finish the year at $31 to $35. The Metal Bulletin published price for tantalite rose from $29 to $35 per pound of contained Ta_2O_5 to $34 to $37 by yearend. The Metal Bulletin published price for tantalite produced by Greenbushes Ltd. of Australia, on the basis of 40% contained Ta_2O_5, remained unchanged at $50 per pound. A published price for tantalite from the Canadian producer, Tantalum Mining Corp. of Canada Ltd. (TANCO), was not available. Tantalum capacitor-grade powder reportedly sold for about $120 per pound, and tantalum mill products reportedly sold for about $160 per pound.

Foreign Trade

Net trade for columbium and tantalum remained at a deficit, but closed to about one-half the 1989 deficit. Overall trade value for exports was relatively unchanged, with total volume up by 25%, owing to a significant increase in the volume of ferrocolumbium exports to Canada. Exports of columbium and tantalum ores and concentrates decreased substantially to 108,000 pounds valued at $365,000. Germany was the principal recipient, with more than 50% of total shipments. For imports, trade volume and value were down appreciably for most items, the major exception being a significant increase in columbium oxide imports from Brazil.

Imports for consumption of columbium mineral concentrates were virtually unchanged from those of 1989. Canada remained the leading supplier, providing almost all of both total quantity and total value. Imports at an average grade of approximately 61% Cb_2O_5 and less than 1% Ta_2O_5 were estimated to contain 2.12 million pounds of columbium and a small quantity of tantalum.

Imports for consumption of tantalum mineral concentrates declined substantially, with the average unit value for overall imports decreasing by more than 15%. Imports from Belgium-Luxembourg and the Federal Republic of Germany, both nonproducing countries, together accounted for about 50% of total quantity and value. Imports at an average grade of approximately 35% Ta_2O_5 and 23% Cb_2O_5 were estimated to contain 640,000 pounds of tantalum and 360,000 pounds of columbium.

Imports for consumption of synthetic tantalum-columbium concentrates declined significantly: 113,000 pounds valued at $1.5 million compared with 170,000 pounds valued at $2.2 million in 1989. These figures are not included in the salient statistics data.

Brazil continued as the major source for U.S. columbium imports, and the Federal Republic of Germany remained the major source for U.S. tantalum imports (see figures 4 and 5).

World Review

Industry Structure.—Brazil and Canada remained as the major producers of columbium raw materials feedstock, while tantalum raw materials continued to be produced mainly in Australia, Brazil, Canada, and in Thailand in the form of high-grade tantalum-bearing tin slags. Synthetic concentrates, produced from low-grade tin slags, from the Federal Republic of Germany were an additional source of columbium and tantalum raw material supply. Principal world raw material and product producers are shown in tables 15 and 16, respectively.

Capacity.—The data in table 17 are rated capacity for mines and mills as of December 31, 1990. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgement of the author, can be brought into production

TABLE 9

REPORTED SHIPMENTS OF COLUMBIUM AND TANTALUM MATERIALS

(Pounds of metal content)

Material	1989	1990
Columbium products:		
Compounds, including alloys	993,575	NA
Metal, including worked products	465,800	NA
Other	—	NA
Total	1,459,375	NA
Tantalum products:		
Oxides and salts	7,260	NA
Alloy additive	77,890	NA
Carbide	NA	NA
Powder and anodes	448,400	NA
Ingot (unworked consolidated metal)	1,000	NA
Mill products	275,200	NA
Scrap	10,200	NA
Other	—	NA
Total	819,950	NA

NA Not available.

Source: Tantalum Producers Association.

TABLE 10

CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES

(Pounds of contained columbium[1])

	1989	1990
END USE		
Steel:		
Carbon	^{r}1,789,523	2,050,705
Stainless and heat-resisting	^{r}867,689	796,351
Full alloy	(2)	(2)
High-strength low-alloy	1,823,685	1,787,363
Electric	—	—
Tool	(3)	(3)
Unspecified	64,959	27,220
Total	^{r}4,545,856	4,661,639
Superalloys	^{r}788,143	999,725
Alloys (excluding alloy steels and superalloys)	(4)	(4)
Miscellaneous and unspecified	42,967	37,200
Total consumption	^{r}5,376,966	5,698,564
STOCKS		
Dec. 31:		
Consumer	NA	NA
Producer[5]	NA	NA
Total stocks[e]	NA	NA

[e] Estimated. [r] Revised. NA Not available.

[1] Includes columbium and tantalum in ferrotantalum-columbium, if any.

[2] Included with "Steel: High-strength low-alloy."

[3] Included with "Steel: Unspecified."

[4] Included with "Miscellaneous and unspecified."

[5] Ferrocolumbium only.

within a short period of time with minimum capital expenditure. Mine capacity for columbium and tantalum is based on published reports, maximum production statistics, and estimates where capacity information is either incomplete or unavailable.

Australia.—For its fiscal year ending June 30, 1990, Gwalia Consolidated Ltd. reported that, as a result of mergers, all company operations at Greenbushes have been consolidated and will be conducted as a single business unit known as the "Greenbushes Mine." Ore treated at Greenbushes was down by about 30% to 1.7 million tons, with tantalum oxide production in tantalum concentrates decreasing to about 203,000 pounds. The tailings retreatment plant produced 99,400 pounds of Ta_2O_5 contained in tantalum concentrates, and tantalum oxide contained in tantalum glass (slag) production rose to 87,000 pounds. The mine's chemical plant produced 12,300 pounds of Ta_2O_5 and 4,700 pounds of Cb_2O_5, both down from the production levels of 1989. Feasibility and marketing studies were being conducted to make a decision, prior to March 1991, with respect to future mine operation and the marketing of products produced.[1]

Brazil.—Production of ferrocolumbium was 17,747 tons, 14,440 tons produced by Cia. Brasileira de Metalurgia e Mineração (CBMM) and 3,307 tons produced by Mineração Catalão de Goiãs S.A. (CATALAO). CBMM also produced 1,709 tons of columbium oxide, up considerably from the 418 tons produced in 1989. CBMM reportedly started construction of a new ferrocolumbium plant in Araxa. With a planned annual ferrocolumbium capacity of about 25,000 tons, the plant will cost about $8 million to construct. The new facility is said to be more cost effective, will allow for production of ferrocolumbium to a tighter specification, and will eliminate atmospheric pollution.

Canada.—As reported by Teck Corp. (operator) and Cambior Inc. (product marketing and sales), production of Cb_2O_5 at the Niobec Mine at St. Honoré, Quebec, a 50-50 joint venture, was down from the record level in 1989 to 7.5 million pounds. Ore milled was virtually unchanged at 876,000 tons, as the mill operated on the average of 2,399 tons of ore per day. Average recovery was

FIGURE 2

U.S. COLUMBIUM END USE IN 1990

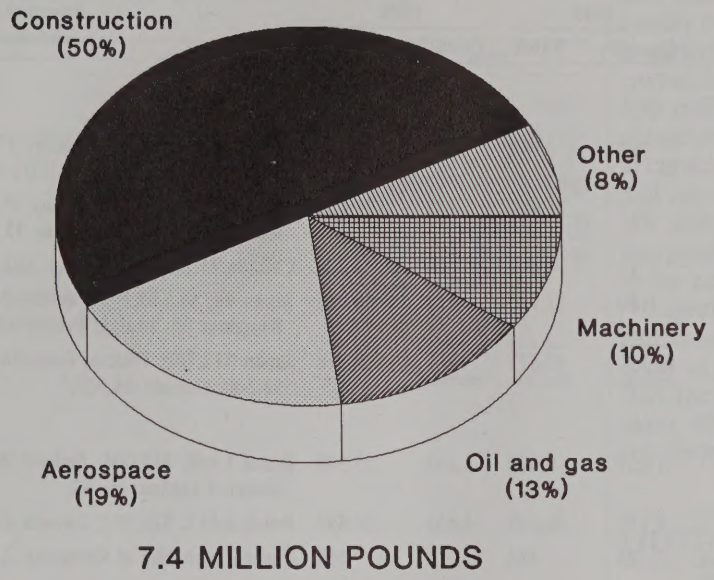


FIGURE 3

U.S. TANTALUM END USE IN 1990

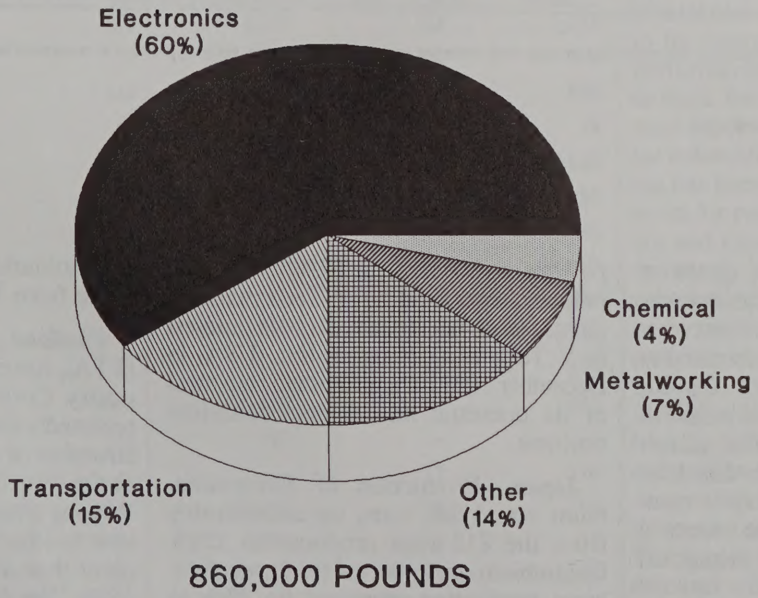


TABLE 11

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS

(Thousand pounds, gross weight, and thousand dollars)

Class	1989		1990		Principal destinations and sources, 1990
	Quantity	Value	Quantity	Value	
EXPORTS[1]					
Tantalum:					
Unwrought and waste and scrap	167	3,412	196	3,862	Federal Republic of Germany 176, $2,993; Canada 12, $481; Belgium-Luxembourg 2, $126; Austria 2, $89; Netherlands 2, $82.
Unwrought powders	211	21,451	182	21,638	Federal Republic of Germany 55, $6,177; France 38, $4,303; United Kingdom 35, $4,202; Japan 35, $3,957; Spain 10, $1,202.
Unwrought alloys and metal	11	1,099	28	3,700	Canada 25, $3,324; Japan 1, $88; Spain 1, $69; Netherlands (2), $49.
Wrought	180	21,715	132	20,068	Japan 58, $8,650; Federal Republic of Germany 18, $3,204; United Kingdom 23, $3,049; France 12, $2,458; Canada 11, $1,088.
Total	XX	47,677	XX	49,268	Japan $12,700; Federal Republic of Germany $12,500; France $6,800; Canada $4,900.[3]
IMPORTS FOR CONSUMPTION					
Columbium:					
Oxide	1,454	9,470	2,145	15,348	Brazil 1,958, $13,006; Federal Republic of Germany 187, $2,339; United Kingdom (2), $2.
Ferrocolumbium	8,178	28,657	6,435	24,685	Brazil 6,412, $24,587; Canada 23, $98.
Unwrought alloys, metal, and powders	26	514	5	150	Federal Republic of Germany 2, $78; Brazil 3, $72.
Tantalum:					
Unwrought waste and scrap	159	7,142	169	6,990	Federal Republic of Germany 74, $4,355; France 27, $821; United Kingdom 13, $550; Taiwan 13, $476.
Unwrought powders	45	2,880	28	2,038	Federal Republic of Germany 13, $1,056; Hong Kong 10, $692; Australia 1, $63.
Unwrought alloys and metal	35	1,573	12	733	Federal Republic of Germany 5, $379; France 3, $148; Austria 2, $100; Australia 2, $92.
Wrought	2	431	7	1,028	Federal Republic of Germany 2, $593; Canada 4, $416; Austria (2), $10; United Kingdom (2), $4.
Total	XX	50,667	XX	50,972	Brazil $37,700; Federal Republic of Germany $8,800; France $1,000.[3]

XX Not applicable.

[1] For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classifications.

[2] Less than 1/2 unit.

[3] Rounded.

Sources: Bureau of the Census and U.S. Bureau of Mines.

down to 60.4% with Cb_2O_5 grade of concentrate at 71%. Lower recovery was attributed to treatment of more refractory ore. Yearend ore reserves decreased to 11 million tons assaying 0.65% Cb_2O_5, reportedly sufficient for 14 years of production. Expansion of the mine's tailings storage capacity is scheduled for late 1991. When construction is completed on the tailings pond, the mine will have an additional 12 years of storage capacity.

Germany, Federal Republic of.—Hermann C. Starck Berlin KG announced that it had increased its holding in V Tech of Japan, a tantalum capacitor powder producer, to 92%, with the balance being held by V Tech management. Starck had acquired a 54% interest in V Tech from Fansteel Inc. (USA) in December 1989, when Fansteel sold most of its domestic and foreign tantalum business.

Japan.—Production of ferrocolumbium was 1,085 tons, up considerably from the 812 tons produced in 1989. Columbium ore imported for ferrocolumbium production increased by 70% to 1,291 tons, with Canada providing more than 80% of the total. Ferrocolumbium imports fell to 3,876 tons from the 3,957 tons reported in 1989. The bulk of ferrocolumbium imports continued to come from Brazil.

Thailand.—Thai Tantalum Co. Ltd. (TTA), formerly Thailand Tantalum Industry Corp. Ltd. (TTIC) of Bangkok, reportedly commenced civil work for construction of a tantalum-processing plant at the Map Ta Phut Industrial Estate in Rayong Province east of Bangkok. The new facility will replace TTA's tantalum plant that was destroyed by fire in June 1986. The fire followed demonstrations by protestors against the opening of the chemical plant because of environmental concerns over the plant's waste treatment facilities and acid storage areas.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM MINERAL CONCENTRATES, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	1989		1990	
	Gross weight	Value	Gross weight	Value
Brazil	12	281	53	91
Canada	4,879	7,368	4,899	7,787
Zaire	—	—	11	20
Total[1]	4,891	7,649	4,964	7,898

[1] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and U.S. Bureau of Mines.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TANTALUM MINERAL CONCENTRATES, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	1989		1990	
	Gross weight	Value	Gross weight	Value
Australia	118	2,322	163	2,835
Austria[1]	1	62	—	—
Belgium-Luxembourg[1]	244	3,036	92	886
Bolivia	3	75	3	38
Brazil	244	2,873	338	3,563
Burundi[1]	—	—	21	250
Canada	154	2,429	253	2,795
Germany, Federal Republic of[1]	2,085	26,918	1,081	11,985
Hong Kong[1]	77	1,279	—	—
Japan[1]	120	1,796	—	—
Malaysia	—	—	12	143
Netherlands[1]	491	7,417	14	203
Singapore[1]	52	747	—	—
Spain	—	—	13	116
Thailand	118	2,073	39	490
United Kingdom[1]	29	566	1	19
Zaire	112	1,124	167	1,895
Zimbabwe	2	43	44	371
Total[2]	3,850	52,762	2,240	25,589

[1] Presumably country of transshipment rather than original source.

[2] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and U.S. Bureau of Mines.

Completion of major civil work is planned by third quarter 1991, with production of columbium oxide and potassium fluotantalate to commence first quarter 1992. Availability of high-quality tantalum capacitor-grade powders is anticipated by first quarter 1992. The cost of the facility has been estimated at $30 million and will have a combined columbium and tantalum product annual capacity of about 600 tons. The plant will use domestically produced columbium and tantalum feedstock materials, and product production will be exclusively for export.

Laporte Ltd. of Thailand reportedly began construction of a hydrofluoric acid plant at Map Ta Phut. TTA indicates that the plant will supply the tantalum plant with all of its hydrofluoric acid requirements.

OUTLOOK

Columbium

Columbium is used principally as an additive in steelmaking, which has accounted for about 80% of the reported consumption in the United States in recent years. No significant change to this trend is expected in the near term for there are few other growth markets and/or uses for columbium. Thus, future columbium demand growth will continue to be directly related to the worldwide performance of the steel industry. The outlook for steel is discussed in the annual report for Iron and Steel. A boost for columbium consumption in steelmaking has been the price volatility in recent years for competing ferroalloys of titanium and vanadium. Some steel companies reportedly have initiated projects for the substitution of columbium for titanium and vanadium in steelmaking. Domestic columbium consumption in the production of superalloys is currently about 15%. Future growth for this end use will be affected mainly by the demand for columbium-containing superalloys from the aircraft industry, which continues to have an up and down cyclical history. The major components of U.S. supply-demand relationships for columbium in 1980-90 are given in table 19.

Tantalum

During the 1980's, more than 60% of the tantalum consumed in the United

TABLE 14

U.S. IMPORT DUTIES ON COLUMBIUM AND TANTALUM MATERIALS

Item	HTSUS No.	Rate of duty effective January 1, 1990	
		Most favored nation (MFN)	Non-MFN
Synthetic tantalum-columbium concentrates	2615.90.3000	Free	30.0% ad valorem.
Columbium ores and concentrates	2615.90.6030	do.	Free.
Tantalum ores and concentrates	2615.90.6060	do.	Do.
Columbium oxide	2825.90.1500	3.7% ad valorem[1,2,3]	25.0% ad valorem.
Tantalum oxide	2825.90.6090[4]	3.7% ad valorem[1,3]	Do.
Potassium fluotantalate	2826.90.0000[4]	3.1% ad valorem[1,5]	Do.
Ferrocolumbium	7202.93.0000	5.0% ad valorem[6,7]	Do.
Unwrought tantalum waste and scrap	8103.10.3000	Free	Free.
Unwrought tantalum powders	8103.10.6030	3.7% ad valorem[1,3]	25.0% ad valorem.
Unwrought tantalum alloys and metal	8103.10.6090	do.	Do.
Wrought tantalum	8103.90.0000	5.5% ad valorem[1,8]	45.0% ad valorem.
Unwrought columbium waste and scrap	8112.91.0500[4]	Free	Free.
Unwrought columbium alloys, metal, and powders	8112.91.4000	4.9% ad valorem[6,9]	25.0% ad valorem.
Wrought columbium	8112.99.0000[4]	5.5% ad valorem[1,8]	45.0% ad valorem.

[1] Free from certain beneficiary countries under the Generalized System of Preferences (GSP), from beneficiary countries under the Caribbean Basin Economic Recovery Act (CBERA), and for products of Israel.

[2] Not duty free for Brazil.

[3] 2.2% ad valorem for products of Canada.

[4] Nonspecific tariff classification.

[5] 1.8% ad valorem for products of Canada.

[6] Free from beneficiary countries under the CBERA and for products of Israel.

[7] 3% ad valorem for products of Canada.

[8] 3.3% ad valorem for products of Canada.

[9] 2.9% ad valorem for products of Canada.

FIGURE 4

MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

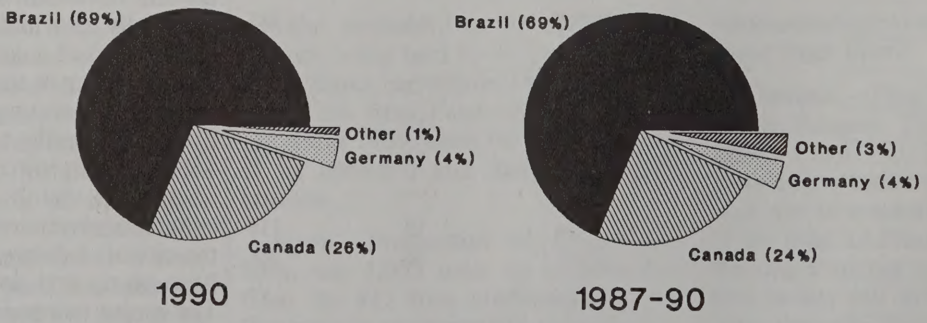


FIGURE 5

MAJOR SOURCES OF U.S. TANTALUM IMPORTS

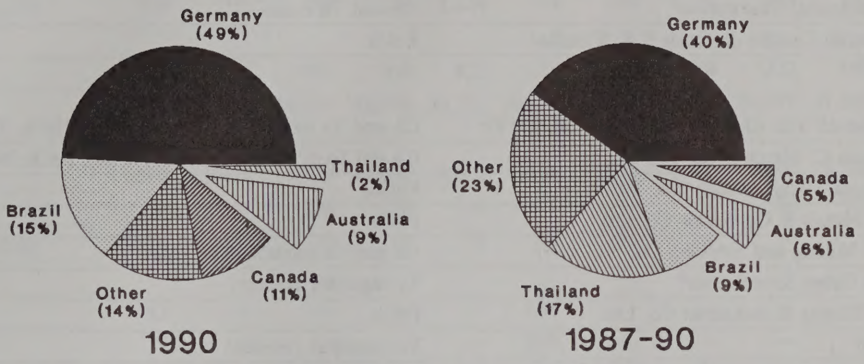


TABLE 15

PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

	MINING OF COLUMBIUM- AND TANTALUM-BEARING ORES	
Country	Company and/or Mine	Material type
Australia	Gwalia Consolidated Ltd. (Greenbushes)	Columbium/tantalum.
	Pan West Tantalum Pty. Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineração (CBMM) (Araxa)	Columbium.
	Cia. de Estanho Minas Brasil (MIBRA)[1]	Columbium/tantalum.
	Paranapanema S.A. Mineração Indústria e Construção (Pitinga)	Columbium/tantalum.
	Mineração Catalão de Goiás S.A. (Catalão)	Columbium.
Canada	Cambior/Teck Corp. (Niobec)	Columbium.
	Tantalum Mining Corp. of Canada Ltd. (Tanco)	Tantalum.
China	Government-owned	Columbium/tantalum.
U.S.S.R.	Government-owned	Columbium/tantalum.
Zaire	Société Minière du Kivu (SOMIKIVU)[1]	Columbium.
	PRODUCTION OF COLUMBIUM- AND TANTALUM-BEARING TIN SLAGS	
Australia	Gwalia Consolidated Ltd. (Greenbushes)	
Brazil	Cia. Industrial Fluminense.[1]	
	Mamoré Mineração e Metalurgia.[2]	
Malaysia	Malaysia Smelting Corp. Sdn. Bhd.	
Thailand	Thailand Smelting and Refining Co. Ltd. (Thaisarco).	
	PRODUCTION OF COLUMBIUM- AND TANTALUM-BEARING SYNTHETIC CONCENTRATES	
Germany, Federal Republic of		
Western states	Gesellschaft Für Elektrometallurgie mbH (GFE).[1]	
	Hermann C. Starck Berlin KG.	

[1] A wholly owned subsidiary of Metallurg Inc., New York.

[2] A subsidiary of Paranapanema S.A. Mineração Indústria e Construção.

TABLE 16

PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products[1]
Australia	Gwalia Consolidated Ltd. (Greenbushes)	Cb and Ta oxide.
Austria	Treibacher Chemische Werke AG	Cb and Ta oxide/carbide, FeCb, NiCb.
Brazil	Cia. Brasileira de Metalurgia e Mineração (CBMM)	Cb oxide/metal, FeCb, NiCb.
	Cia. Industrial Fluminense[2]	Cb and Ta oxide.
	Mineração Catalão de Goiás S.A. (Catalão)	FeCb.
Germany, Federal Republic of:		
Western states	Gesellschaft Für Elektrometallurgie mbH (GFE)[2]	Cb and Ta oxide/metal, K-salt, FeCb, NiCb, Ta capacitor powder.
	Hermann C. Starck Berlin KG	Cb and Ta oxide/metal/carbide, K-salt, FeCb, NiCb, Ta capacitor powder.
Japan	Awamura Metal Industry Co. Ltd.	FeCb.
	Japan Metals & Chemicals Co. Ltd.	FeCb.
	Mitsui Mining and Smelting Co.	Cb and Ta oxide/metal/carbide.
	Showa Cabot Supermetals[3]	Ta capacitor powder.
	Taiyo Mining & Industrial Co. Ltd.	FeCb.
	V Tech[4]	Ta capacitor powder.
United Kingdom	London & Scandinavian Metallurgical Co. Ltd.[2]	Cb and Ta carbide.
United States	Cabot Corp.	Cb and Ta oxide/metal, K-salt, FeCb, NiCb, Ta capacitor powder.
	Kennametal, Inc.	Cb and Ta carbide.
	NRC, Inc.[5]	Cb and Ta metal, Ta capacitor powder.
	Reading Alloys, Inc.	FeCb, NiCb.
	Shieldalloy Metallurgical Corp.[2]	FeCb, NiCb.
	Teledyne Wah Chang Albany	Cb oxide/metal, FeCb, NiCb.

[1] Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
[2] A wholly owned subsidiary of Metallurg Inc., New York.
[3] A joint venture between Showa Denko and Cabot Corp.
[4] A subsidiary of Hermann C. Starck Berlin KG.
[5] Jointly owned by Bayer U.S.A. Inc. and Hermann C. Starck Berlin KG.

TABLE 17

WORLD COLUMBIUM AND TANTALUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1990

(Thousand pounds of columbium or tantalum content)

Country	Rated capacity[1][2]	
	Columbium	Tantalum
North America:		
Canada	5,000	200
United States	—	—
Total	5,000	200
South America: Brazil	40,000	400
Africa:		
Nigeria	400	100
Zaire	100	100
Other	200	200
Total	700	400
Asia:		
Malaysia	200	200
Thailand	600	800
Total	800	1,000
Oceania: Australia	200	400
World total (may be rounded)	47,000	2,400

[1] Includes capacity at operating facilities as well as facilities on standby basis.
[2] Includes estimated byproduct recovery as tin slag.

States was used to produce electronic components, mainly tantalum capacitors, with major markets in recent years being computer and communication systems. However, overall tantalum demand growth in this sector has been slowed because of the industry's continued emphasis on higher capacitance powders and the miniaturization of electronic components resulting in less tantalum used per unit. A similar situation exists for tantalum in cemented carbide use. Tantalum demand in this market has been affected by the growing use of mixed carbides, coated cutting tools, improved tool life, and the down-sizing of components. Additionally, the demand and price for tantalum has had a cyclical and somewhat volatile history. Thus, the future growth for tantalum will continue to depend not only on the fortunes of the electronic and carbide industries but also on tantalum's price stability. The major components of U.S. supply-demand relationships for tantalum in 1980–90 are given in table 20.

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[1] Gwalia Consolidated Ltd. 1990 Annual Report. 59 pp.

TABLE 18

COLUMBIUM AND TANTALUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1]

(Thousand pounds)

Country[2]	Gross weight[3]					Columbium content[e,4]					Tantalum content[e,4]				
	1986	1987	1988	1989	1990[e]	1986	1987	1988	1989	1990	1986	1987	1988	1989	1990
Australia: Columbite-tantalite	309	351	498	1,224	1,224	64	60	70	141	141	109	115	164	263	263
Brazil:															
Columbite-tantalite	604	[r]985	[r]888	[r]961	822	139	226	[r]204	[r]222	190	175	285	[r]257	[r]279	239
Pyrochlore	63,354	[r]37,734	[r]74,547	[r]58,045	50,706	26,610	[r]15,849	[r]31,310	[r]24,379	21,385	—	—	—	—	—
Canada:[e]															
Pyrochlore	11,500	9,490	11,530	12,000	11,622	5,160	4,270	5,190	5,400	5,230	—	—	—	—	—
Tantalite	—	—	200	650	730	—	—	8	20	21	—	—	60	160	180
Malaysia: Columbite-tantalite	474	503	—	—	[5]9	71	75	—	—	1	33	35	—	—	1
Mozambique:															
Microlite	[e]13	—	—	—	—	NA	—	—	—	—	7	—	—	—	—
Tantalite	[e]9	—	—	—	—	NA	—	—	—	—	3	—	—	—	—
Namibia: Tantalite	18	30	[r]15	[r]13	11	3	3	[r]2	[r]1	2	3	5	[r]2	[r]1	2
Nigeria: Columbite	29	106	110	[r]101	[5]97	12	45	46	[r]43	41	2	6	6	6	5
Portugal: Tantalite	13	—	—	—	—	3	—	—	—	—	4	—	—	—	—
Rwanda: Columbite-tantalite	—	—	(6)	(6)	(6)	—	—	(6)	(6)	(6)	—	—	(6)	(6)	(6)
South Africa, Republic of:															
Columbite-tantalite	—	(6)	(6)	(6)	(6)	—	(6)	(6)	(6)	(6)	—	(6)	(6)	(6)	(6)
Spain: Tantalite	[e]26	[e]22	24	[e]24	24	NA	NA	NA	NA	NA	7	6	6	6	6
Thailand: Columbite-tantalite	267	403	273	240	[5]20	46	69	46	41	3	73	109	74	65	5
Zaire: Columbite-tantalite	[e]110	[e]110	[r]74	[r]106	110	30	30	[r]19	[r]28	29	31	31	[r]21	[r]30	31
Zimbabwe: Columbite-tantalite	73	82	146	71	73	11	6	22	11	11	26	13	51	25	26
Total	76,799	[r]49,816	[r]88,305	[r]73,435	65,448	32,149	[r]20,633	[r]36,917	[r]30,286	27,054	473	605	[r]641	[r]835	758

[e]Estimated. [r]Revised. NA Not available.

[1] Excludes columbium- and tantalum-bearing tin slags. Production of tantalum contained in tin slags was, in thousand pounds, 1986—623; 1987—543; 1988—1,145; 1989—799; and 1990—756 according to data from the Tantalum-Niobium International Study Center. Table includes data available through June 21, 1991.

[2] In addition to the countries listed, China, the U.S.S.R., and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[3] Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups such as columbite and tantalite where it is not.

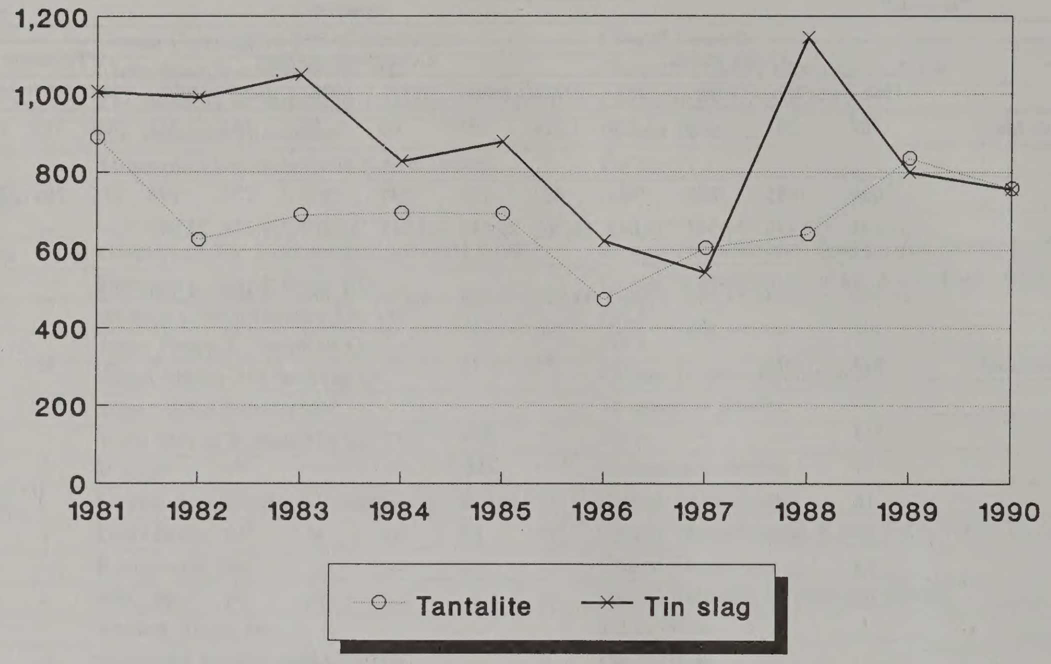
[4] Unless otherwise specified, data presented for metal content are U.S. Bureau of Mines estimates based on, in most part, reported gross weight and/or pentoxide content. Metal content estimates are revised as necessary to reflect changes in gross weight and/or pentoxide data.

[5] Reported in and/or by official country sources.

[6] Less than 1/2 unit.

FIGURE 6

WORLD TANTALUM SUPPLY



THOUSAND POUNDS TANTALUM

TABLE 19

COLUMBIUM SUPPLY-DEMAND RELATIONSHIPS

(Thousand pounds columbium content)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990^{p}
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
Domestic mine production	(1)	(1)	(1)	—	—	—	—	—	—	(1)	(1)
Shipments of Government stockpile excesses	—	—	—	—	—	—	—	—	—	—	—
Imports^{2}	9,728	7,960	^{e}4,353	W	W	W	W	W	NA	NA	NA
Industry stocks, Jan. 1	6,631	8,581	8,332	W	W	W	W	W	NA	NA	NA
Total U.S. supply	16,359	16,541	12,685	W	W	W	W	W	NA	NA	NA
Distribution of U.S. supply:											
Industry stocks, Dec. 31	8,581	8,332	^{e}5,971	W	W	W	W	W	NA	NA	NA
Exports^{e}	171	91	88	78	80	77	72	85	100	^{r}230	200
Government accessions	—	—	26	—	—	213	—	—	—	—	—
Industrial demand	7,607	8,118	6,600	5,750	7,670	7,550	7,060	7,300	7,900	^{r}7,500	7,400
U.S. DEMAND PATTERN											
Construction	2,360	3,166	2,706	2,300	2,920	3,320	3,110	3,140	3,710	^{r}3,750	3,700
Machinery:											
Metalworking machinery	210	284	214	173	230	227	211	200	200	^{r}180	180
Special industry machinery	627	853	644	517	614	604	564	610	590	^{r}560	560
Total	837	1,137	858	690	844	831	775	810	790	^{r}740	740
Oil and gas industries	1,215	1,624	1,122	748	1,070	1,130	920	950	790	^{r}980	960
Transportation	2,435	1,623	1,518	1,495	1,990	1,890	1,690	1,530	1,740	^{r}1,430	1,400
Other	760	568	396	517	846	379	565	870	870	^{r}600	600
Total U.S. primary demand	7,607	8,118	6,600	5,750	7,670	7,550	7,060	7,300	7,900	^{r}7,500	7,400

^{e}Estimated. ^{p}Preliminary. ^{r}Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Includes concentrates, ferrocolumbium, tin slags, and other.

TABLE 20

TANTALUM SUPPLY-DEMAND RELATIONSHIPS

(Thousand pounds tantalum content)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990[p]
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
Domestic mine production	(1)	(1)	(1)	—	—	—	—	—	—	(1)	(1)
Secondary[e]	121	95	89	40	130	90	75	125	130	120	120
Shipments of Government stockpile excesses	—	—	—	—	—	—	—	—	—	—	—
Imports[2]	2,280	1,580	[e]1,087	W	W	W	W	W	NA	NA	NA
Industry stocks, Jan. 1	2,753	3,261	3,452	W	W	W	W	W	NA	NA	NA
Total U.S. supply	5,154	4,936	4,628	W	W	W	W	W	NA	NA	NA
Distribution of U.S. supply:											
Industry stocks, Dec. 31	3,261	3,452	[e]3,195	W	W	W	W	W	NA	NA	NA
Exports[e]	706	222	340	262	383	320	312	376	564	[r]430	380
Government accessions	—	—	33	—	—	254	—	—	—	—	—
Industrial demand	1,187	1,262	1,060	1,181	1,680	800	820	840	930	[r]830	860
U.S. DEMAND PATTERN											
Electronic components	862	882	703	733	1,052	444	484	504	610	[r]500	520
Transportation	70	102	121	165	218	131	123	126	70	[r]120	130
Machinery:											
Chemical equipment	72	83	69	47	60	48	44	34	30	[r]30	30
Metalworking machinery	152	192	138	189	264	102	112	59	60	[r]60	60
Total	224	275	207	236	324	150	156	93	90	[r]90	90
Other	31	3	29	47	86	75	57	117	160	[r]120	120
Total demand	1,187	1,262	1,060	1,181	1,680	800	820	840	930	[r]830	860
Total U.S. primary demand (industrial demand less secondary)	1,066	1,167	971	1,141	1,550	710	745	715	800	[r]710	740

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Includes concentrates, tin slag, and other.

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